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(54) **RADIAL PRE-SWIRL ASSEMBLY AND COOLING FLUID METERING STRUCTURE FOR A GAS TURBINE ENGINE**

(75) Inventors: **Vincent P. Laurello**, Hobe Sound, FL (US); **Keith D. Kimmel**, North Palm Beach, FL (US); **Todd Ebert**, West Palm Beach, FL (US)

(73) Assignee: **Siemens Energy, Inc.**, Orlando, FL (US)

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F01D 5/08 (2006.01)

(52) **U.S. Cl.**
USPC **60/806; 415/115; 60/785**

(58) **Field of Classification Search**
USPC 60/782, 784, 785, 805, 806; 415/115
See application file for complete search history.

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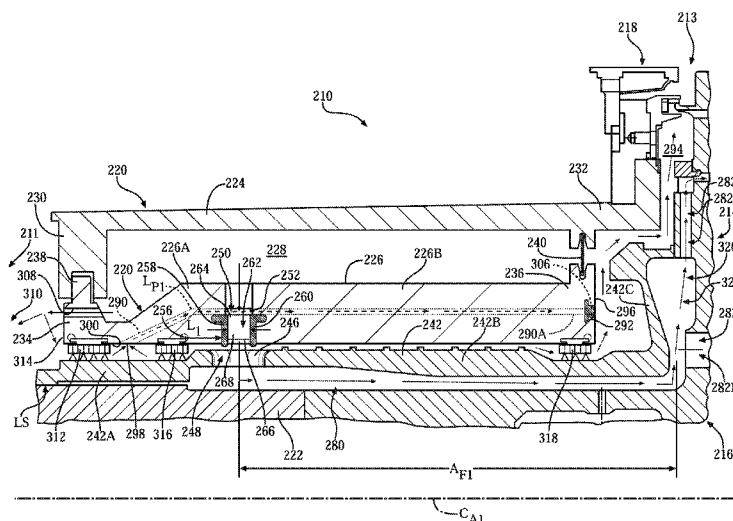
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Primary Examiner — Ted Kim

(57) **ABSTRACT**

A gas turbine engine comprises a pre-swirl structure coupled to a shaft cover structure and located radially between a supply of cooling fluid and a flow path. The pre-swirl structure defines a flow passage and includes a plurality of swirl members in the flow passage. A flow direction of cooling fluid passing through the flow passage is altered by the swirl members such that the cooling fluid has a velocity component in a direction tangential to the circumferential direction. The bypass passages provide cooling fluid into a turbine rim cavity associated with a first row vane assembly to prevent hot gas ingestion into the turbine rim cavity from a hot gas flow path associated with a turbine section of the engine.

20 Claims, 7 Drawing Sheets



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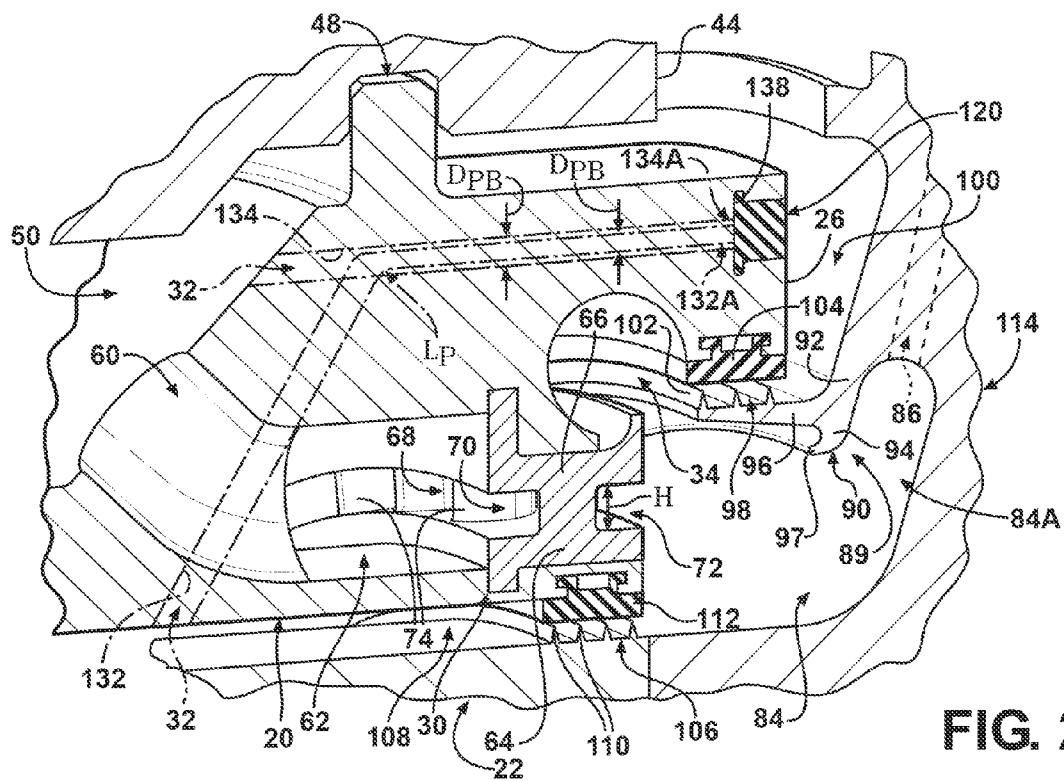


FIG. 2

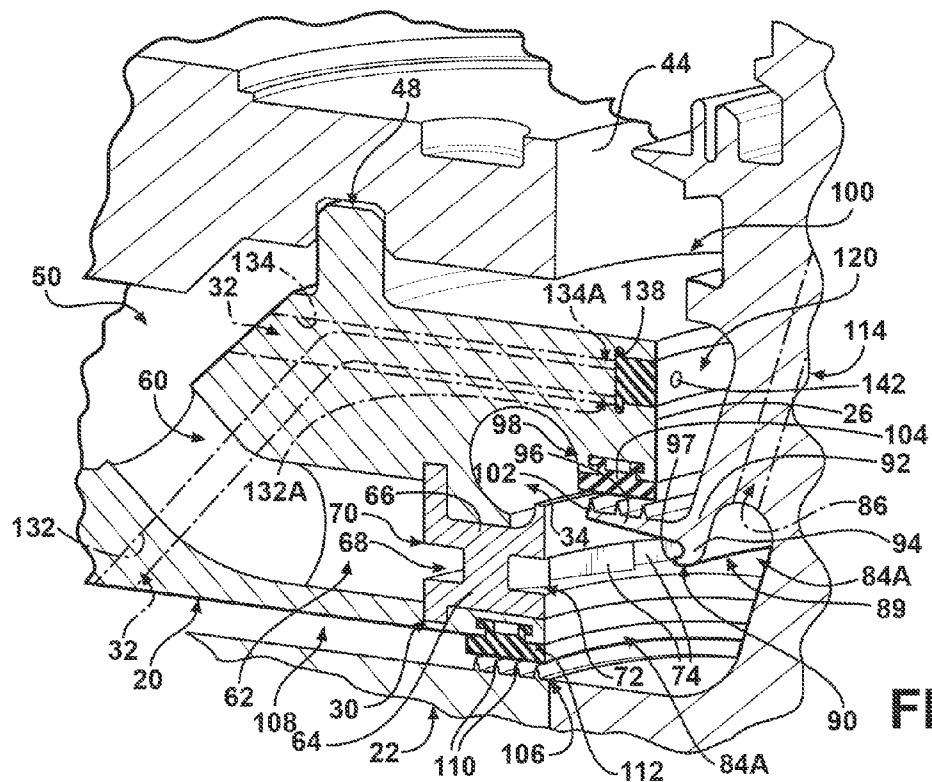


FIG. 3

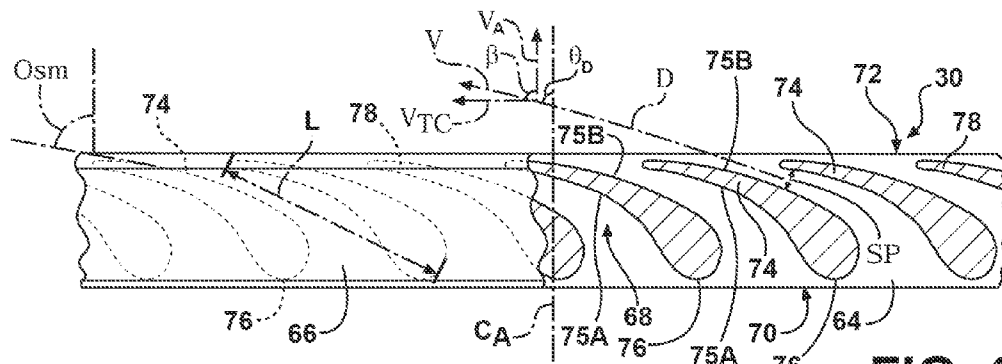


FIG. 4

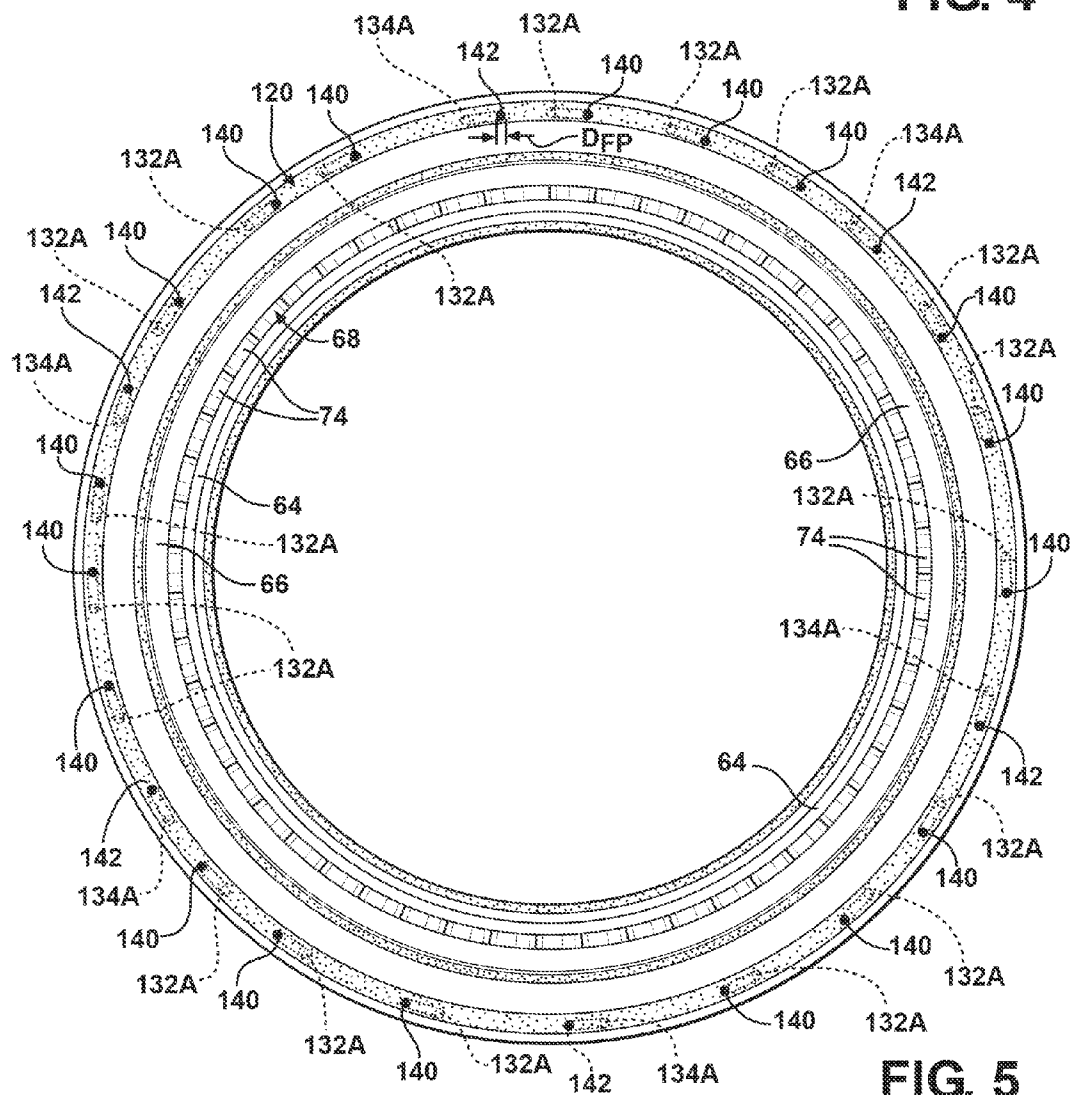


FIG. 5

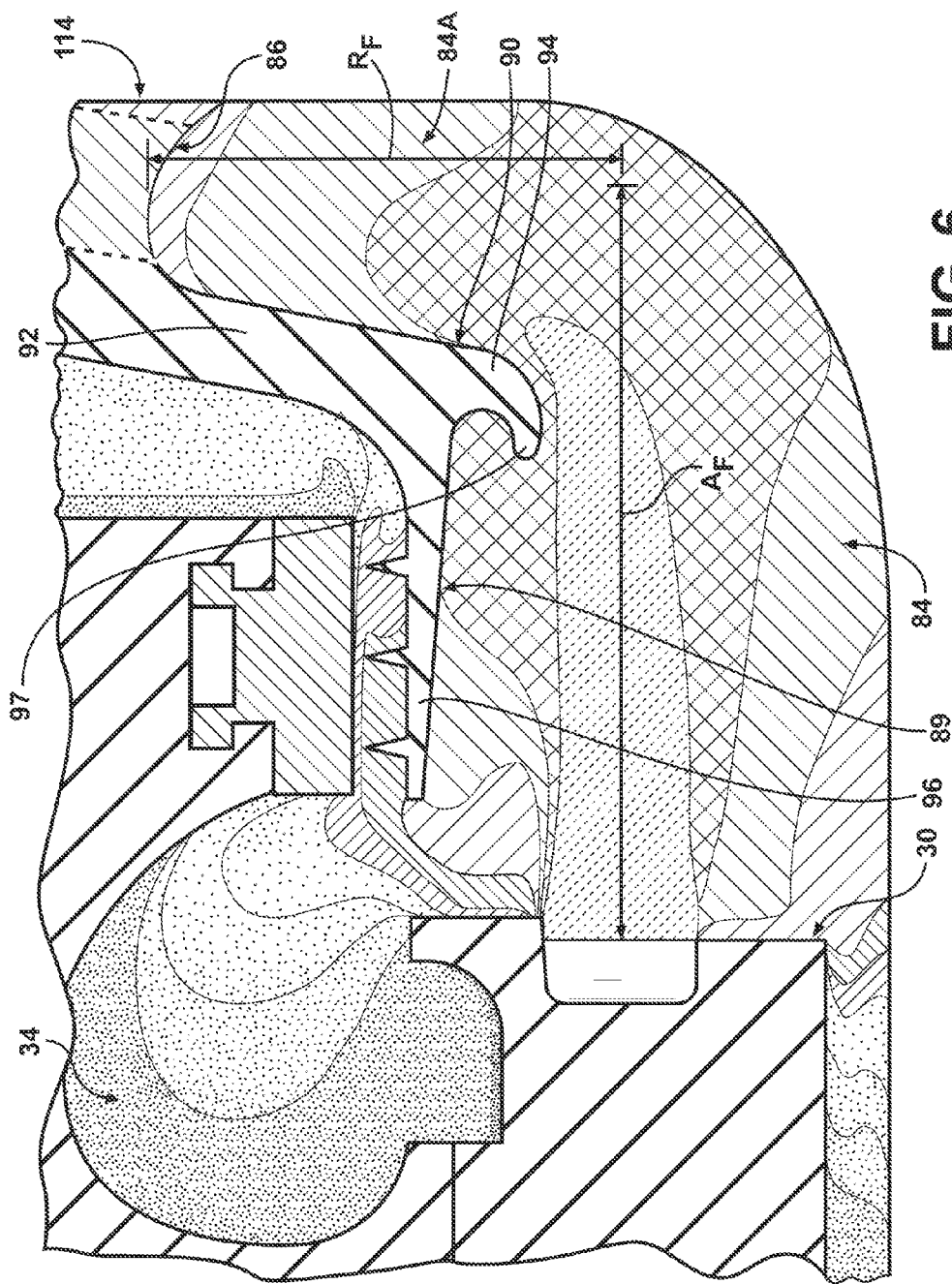


FIG. 6

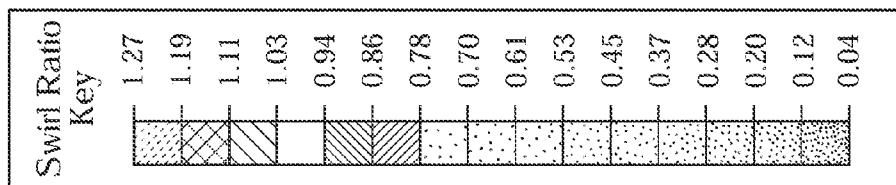
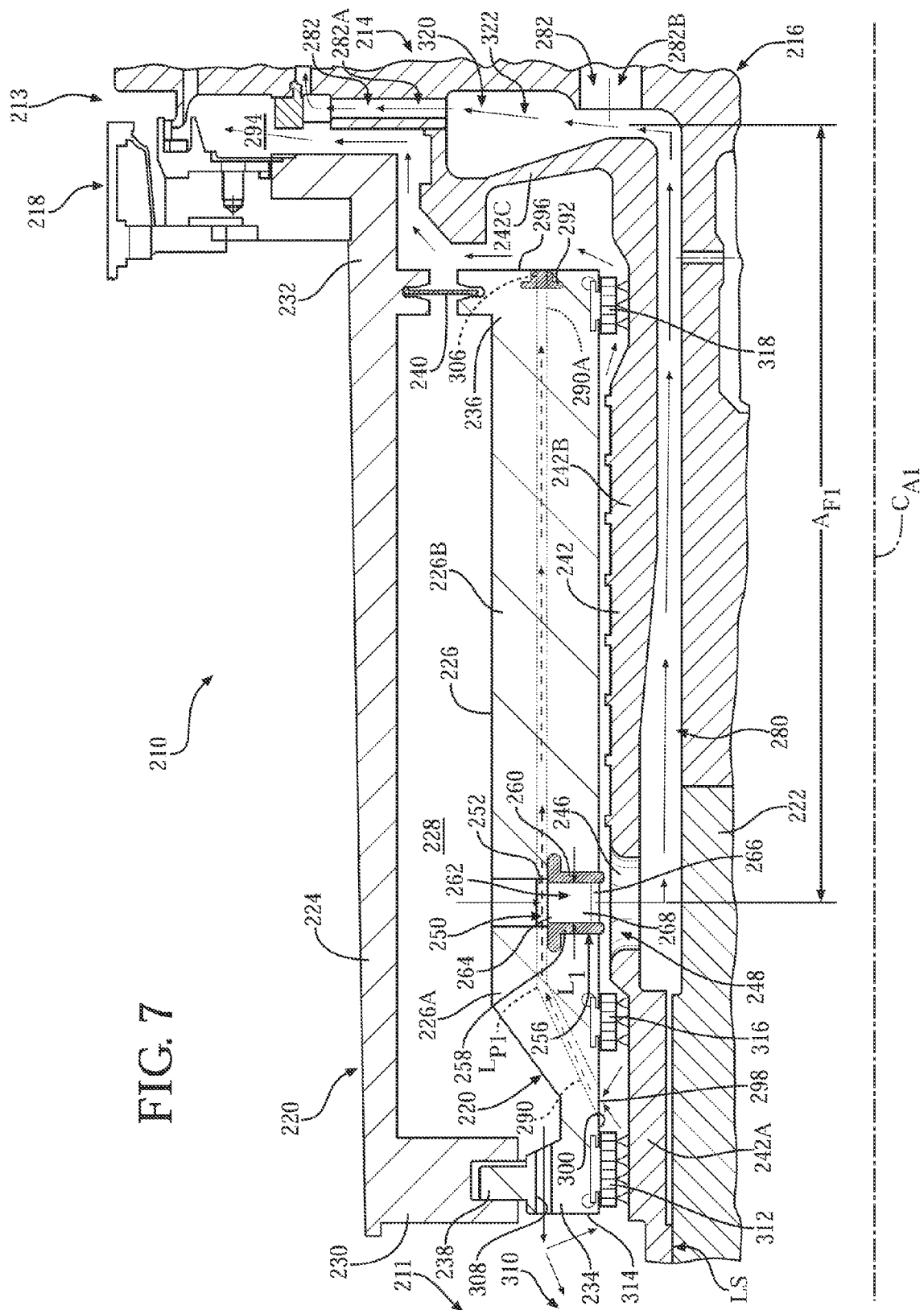


FIG. 7



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G
H
F

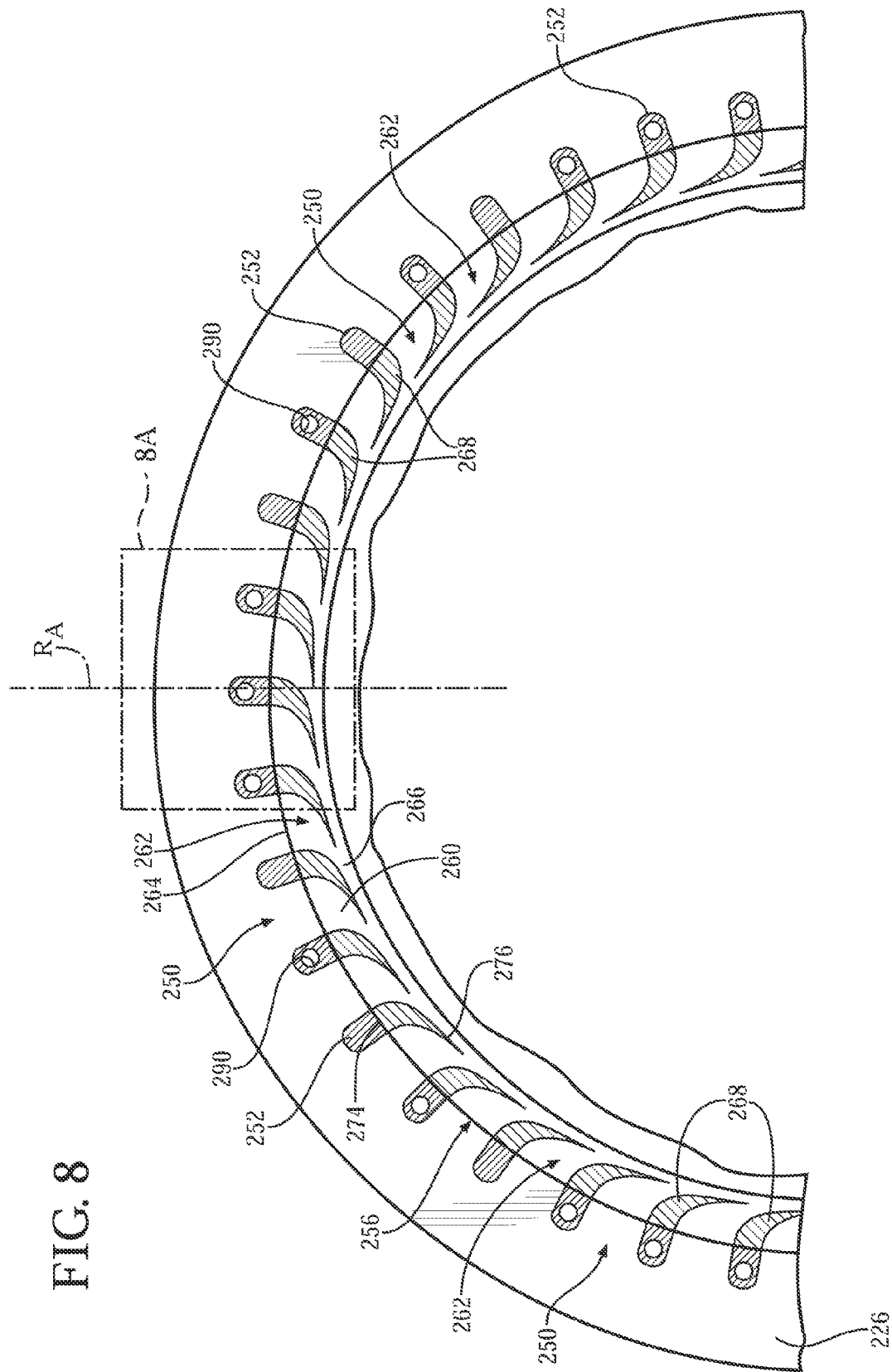
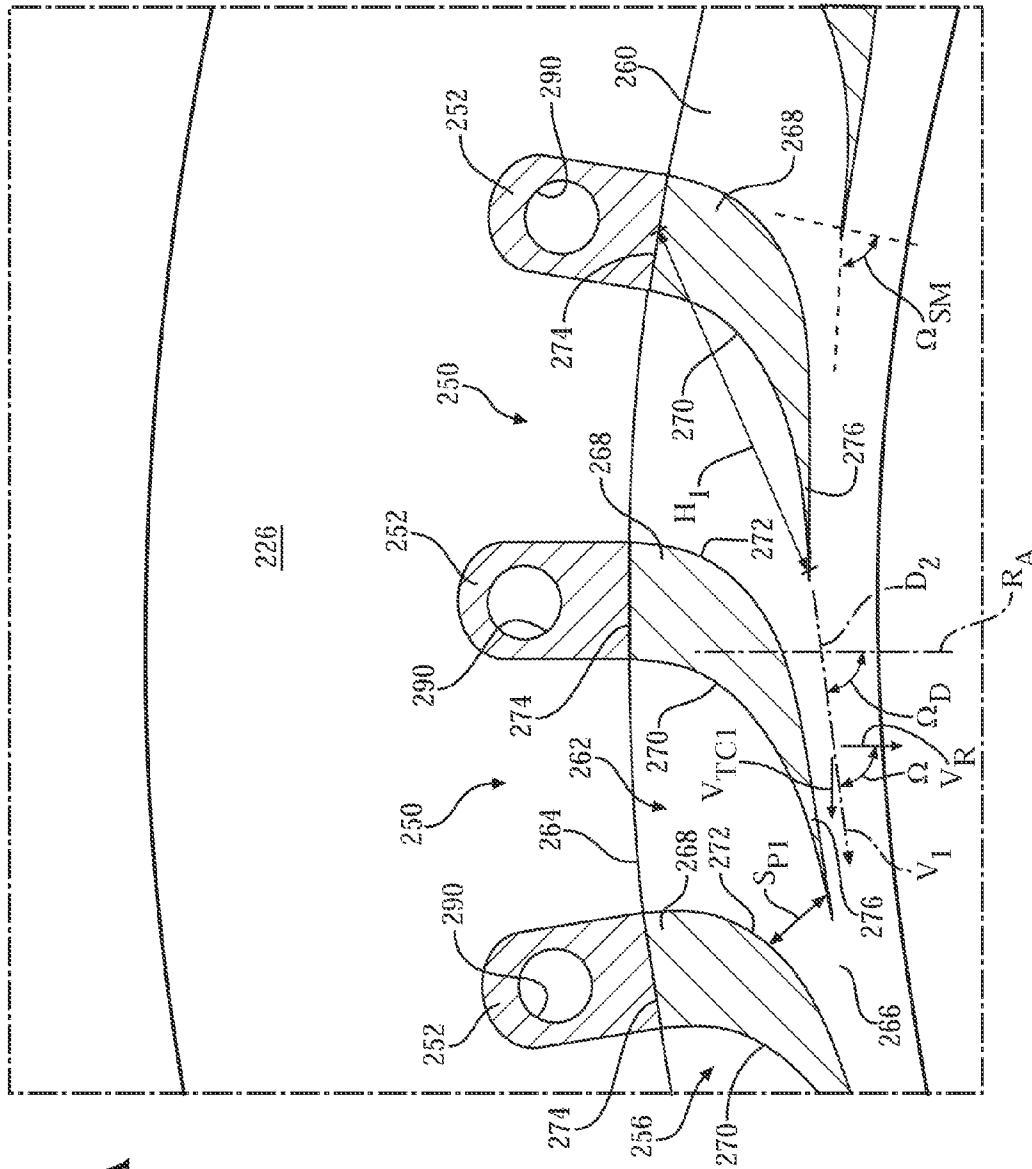


FIG. 8A



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RADIAL PRE-SWIRL ASSEMBLY AND COOLING FLUID METERING STRUCTURE FOR A GAS TURBINE ENGINE

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation-In-Part of U.S. patent application Ser. No. 12/758,069, filed Apr. 12, 2010, entitled "COOLING FLUID METERING STRUCTURE IN A GAS TURBINE ENGINE" by Keith D. Kimmel et al., the entire disclosure of which is incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates to gas turbine engines, and more particularly, to a gas turbine engine including a radial pre-swirl assembly and a metering structure associated with a plurality of bypass passages.

BACKGROUND OF THE INVENTION

In gas turbine engines, compressed air discharged from a compressor section and fuel introduced from a source of fuel are mixed together and burned in a combustion section, creating combustion products defining hot working gases. The working gases are directed through a hot gas path in a turbine section, where they expand to provide rotation of a turbine rotor. The turbine rotor may be linked to an electric generator, wherein the rotation of the turbine rotor can be used to produce electricity in the generator.

In view of high pressure ratios and high engine firing temperatures implemented in modern engines, certain components, such as rotating blade structures within the turbine section, must be cooled with cooling fluid, such as compressor discharge air, to prevent overheating of the components. The rotating components associated with the rotor may be moving at a substantially higher speed than the cooling air supplied for cooling the components such that the cooling air may produce a drag force on the rotating components, which may result in reduced output of the engine and an increased temperature of the cooling air.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the present invention, a gas turbine engine is provided having a central axis defining an axial direction. The engine comprises a supply of cooling fluid, a rotatable shaft extending in the axial direction of the engine, and shaft cover structure disposed about the shaft such that a flow path extends in the axial direction between the shaft and the shaft cover structure. The engine further comprises pre-swirl structure coupled to the shaft cover structure and located radially between the supply of cooling fluid and the flow path, the pre-swirl structure extending in a circumferential direction about the shaft. The pre-swirl structure comprises forward wall structure and aft wall structure spaced in the axial direction from the forward wall structure. The forward and aft wall structures define a flow passage therebetween, the flow passage including an inlet in communication with the supply of cooling fluid and an outlet in communication with the flow path. The flow passage supplies a first portion of cooling fluid from the supply of cooling fluid to the flow path. The pre-swirl structure further comprises a plurality of swirl members in the flow passage extending between the forward and aft wall structures. Each swirl member includes a leading edge and a trailing edge spaced from

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the leading edge in a radial direction, wherein the trailing edge is offset from the leading edge in the circumferential direction. A flow direction of the first portion of cooling fluid passing through the flow passage is altered by the swirl members such that the first portion of cooling fluid has a velocity component in a direction tangential to the circumferential direction when the first portion of cooling fluid enters the flow passage. The engine also comprises at least one bypass passage defined through the shaft cover structure and including an exit opening at an end of the shaft cover structure. The at least one bypass passage receives a second portion of cooling fluid from the supply of cooling fluid and supplies the second portion of cooling fluid to a turbine rim cavity associated with a first row vane assembly to prevent hot gas ingestion into the turbine rim cavity from a hot gas flow path associated with a turbine section of the engine.

In accordance with a second aspect of the present invention, a gas turbine engine is provided having a central axis defining an axial direction. The engine comprises a supply of cooling fluid, a rotatable shaft extending in the axial direction of the engine, and shaft cover structure disposed about the shaft such that a flow path extends in the axial direction between the shaft and the shaft cover structure. The engine further comprises pre-swirl structure coupled to the shaft cover structure and located radially between the supply of cooling fluid and the flow path, the pre-swirl structure extending in a circumferential direction about the shaft. The pre-swirl structure comprises a flow passage including an inlet in communication with the supply of cooling fluid and an outlet in communication with the flow path. The flow passage supplies a first portion of cooling fluid from the supply of cooling fluid to the flow path. The pre-swirl structure further comprises a plurality of swirl members in the flow passage. The swirl members each include a leading edge and a trailing edge spaced from the leading edge in a radial direction, wherein the trailing edge is offset from the leading edge in the circumferential direction. A flow direction of the first portion of cooling fluid passing through the flow passage is altered by the swirl members such that the first portion of cooling fluid has a velocity component in a direction tangential to the circumferential direction when the cooling fluid enters the flow passage. The engine also comprises a plurality of bypass passages associated with the shaft cover structure. The bypass passages receive a second portion of cooling fluid from the supply of cooling fluid and supply the second portion of cooling fluid to a turbine rim cavity associated with a first row vane assembly to prevent hot gas ingestion into the turbine rim cavity from a hot gas flow path associated with a turbine section of the engine. The engine still further comprises a metering structure associated with an outlet of each bypass passage. The metering structure comprising a plurality of flow passageways formed therein for permitting the second portion of cooling fluid in the bypass passages to pass into the turbine rim cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the present invention, it is believed that the present invention will be better understood from the following description in conjunction with the accompanying Drawing Figures, in which like reference numerals identify like elements, and wherein:

FIG. 1 is a sectional view of a portion of a gas turbine engine according to an embodiment of the invention;

FIG. 2 is a perspective view partially in section of a portion of the gas turbine engine illustrated in FIG. 1;

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FIG. 3 is a perspective view partially in section of the portion of the gas turbine engine illustrated in FIG. 2 taken from a different angle;

FIG. 4 is a cross sectional view illustrating a plurality of swirl members according to an embodiment of the invention;

FIG. 5 is an end view of a shaft cover structure according to an embodiment of the invention shown removed from the gas turbine engine illustrated in FIG. 1;

FIG. 6 is a diagram illustrating swirl ratios of cooling fluid passing out of a pre-swirl structure according to an embodiment of the invention;

FIG. 7 is a sectional view of a portion of a gas turbine engine according to another embodiment of the invention;

FIG. 8 is a partial cross sectional view illustrating portions of a shaft cover structure and a pre-swirl structure of the gas turbine engine illustrated in FIG. 7, wherein the shaft cover structure and the pre-swirl structure have been removed from the engine for clarity; and

FIG. 8A is an enlarged view of a portion of FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration, and not by way of limitation, specific preferred embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and that changes may be made without departing from the spirit and scope of the present invention.

Referring now to FIG. 1, a portion of a gas turbine engine 10 according to an embodiment of the invention is shown. The engine 10 includes a conventional compressor section 11 for compressing air. The compressed air from the compressor section 11 is conveyed to a combustion section 12, which produces hot combustion gases by burning fuel in the presence of the compressed air from the compressor section 11. The combustion gases are conveyed through a plurality of transition ducts 12A to a turbine section 13 of the engine 10. The turbine section 13 comprises alternating rows of rotating blades 14 and stationary vanes 18. A first row 14A of circumferentially spaced apart blades 14 coupled to a first blade disc structure 114 and a first row 18A of circumferentially spaced apart vanes 18 coupled to an interior side of a main engine casing (not shown) and a first lower stator support structure 118 are illustrated in FIG. 1. A plurality of the blade disc structures, including the first blade disc structure 114, are positioned adjacent to one another in an axial direction so as to define a rotor 16. Each of the blade disc structures supports a plurality of circumferentially spaced apart blades and each of a plurality of lower stator support structures support a plurality of circumferentially spaced apart vanes. The vanes 18 direct the combustion gases from the transition ducts 12A along a hot gas flow path HG onto the blades 14 such that the combustion gases cause rotation of the blades 14, which in turn causes corresponding rotation of the rotor 16.

As shown in FIG. 1, a shaft cover structure 20 surrounds a portion of a shaft 22, which shaft 22 is coupled to the rotor 16 for rotation with the rotor 16. It is noted that the shaft cover structure 20 may be mounted to the main engine casing and does not rotate with the shaft 22 and the rotor 16 during operation of the engine 10. In an embodiment, the shaft cover structure 20 may comprise two halves or sections that are joined together about the shaft 22, such as, for example, by bolting, although it is understood that the shaft cover structure 20 may be formed from additional or fewer pieces/sections.

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The shaft cover structure 20 comprises a generally cylindrical member having a forward end portion 24 and an opposed aft end portion 26.

Referring still to FIG. 1, the forward end portion 24 of the shaft cover structure 20 includes a shaft seal assembly 28 that creates a substantially fluid tight seal with the shaft 22. The shaft seal assembly 28 may comprise, for example, a rotating structure, such as a knife edge seal, coupled to the shaft 22, which may be in combination with a non-rotating seal structure, such as a honeycomb seal or an abradable material coupled to the forward end portion 24 of the shaft cover structure 20. Other suitable exemplary types of shaft seal assemblies 28 include leaf seals, brush seals, and non-contacting fin seals.

The aft end portion 26 of the shaft cover structure 20 comprises a pre-swirl structure 30 and defines a plurality of bypass passages 32 and a particle collection chamber 34, each of which will be described in detail herein.

An outer cover 40 is disposed radially outwardly from the shaft cover structure 20. The outer cover 40 includes a forward end portion 42 upstream and radially outward from the forward end portion 24 of the shaft cover structure 20 and an aft end portion 44 radially outward from the aft end portion 26 of the shaft cover structure 20. First seal structure 46, such as, for example, a dog bone seal or diaphragm seal is disposed between the forward end portion 24 of the shaft cover structure 20 and the outer cover 40 for creating a substantially fluid tight seal therebetween. Second seal structure 48 is located between the shaft cover structure 20 and the outer cover 40 adjacent to the respective aft end portions 26, 44 thereof. The second seal structure 48 creates a substantially fluid tight seal between the aft end portion 26 of the shaft cover structure 20 and the aft end portion 44 of the outer cover 40. In the embodiment shown, the second seal structure 48 also provides a structural support for the shaft cover structure 20 via the outer cover 40. It is noted that the outer cover 40 is non-rotatable and is structurally supported within the engine 10 by the main engine casing via a plurality of struts (not shown).

A cooling fluid chamber 50 is located radially between the shaft cover structure 20 and the outer cover 40 and axially between the first and second seal structures 46, 48. The cooling fluid chamber 50 receives cooling fluid from a supply of cooling fluid, e.g., compressor bleed air that is cooled in an external cooler (not shown), from a plurality of cooling fluid feed tubes 52 (one shown in FIG. 1). The cooling fluid feed tubes 52 deliver the cooling fluid into the cooling fluid chamber 50 through one or more respective apertures 54 formed in the outer cover 40. The cooling fluid, which may have a temperature of, for example, between about 250-350° F., is used to cool the shaft cover structure 20, the shaft 22, and structure in the turbine section 13 of the engine 10, as will be described in greater detail herein.

Referring additionally to FIGS. 2 and 3, a first portion of cooling fluid supplied by the cooling fluid chamber 50 flows through a series of pre-swirl passages 60 (one shown in FIGS. 1-3) that extend through the shaft cover structure aft end portion 26 from the cooling fluid chamber 50 to an annular pre-swirl chamber 62. The first portion of cooling fluid flows from the pre-swirl passages 60 into the pre-swirl chamber 62 and is provided to the pre-swirl structure 30.

As shown in FIGS. 2 and 3, the pre-swirl structure 30 includes a radially inner wall structure 64 that extends about the shaft 22 and is fixedly coupled to the shaft cover structure 20. The pre-swirl structure 30 also includes a radially outer wall structure 66 radially spaced from the inner wall structure 64. The outer wall structure 66 extends about the shaft 22 and

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is also fixedly coupled to the shaft cover structure 20. The inner and outer wall structures 64, 66 define an annular flow passage 68 therebetween, which flow passage 68 includes an inlet 70 and an outlet 72 (see also FIG. 4), through which the first portion of cooling fluid passes after entering the pre-swirl structure 30 from the pre-swirl chamber 62.

A plurality of swirl members 74 extend in the flow passage 68 and span between the inner and outer wall structures 64, 66. As more clearly shown in FIG. 4, the swirl members 74 each include opposed first and second sidewalls 75A, 75B, a leading edge 76 at the flow passage inlet 70 and a trailing edge 78 at the flow passage outlet 72. The leading edge 76 of each of the swirl members 74 is offset from the trailing edge 78 in the circumferential direction, as shown in FIG. 4. Thus, the first portion of cooling fluid flowing through the flow passage 68 is caused to change direction by the swirl members 74, such that the first portion of cooling fluid exiting the flow passage outlet 72 has a velocity vector V (see FIG. 4) with a velocity component V^{TC} in a direction tangent to a circumferential direction, wherein the circumferential direction is defined by a first circumferential surface of the inner wall structure 64, and an axial velocity component V_A as it flows downstream toward the turbine section 13 of the engine 10, as will be described in detail herein. An angle β between the velocity vector V and its velocity component V_A may be between about 65° and about 85° . A radial height H (see FIG. 2) of each of the swirl members 74 according to an exemplary embodiment of the invention may be about 15-25 mm and a chordal length L (see FIG. 4) of each of the swirl members 74 according to an exemplary embodiment of the invention may be about 60-105 mm according to one embodiment of the invention.

Referring to FIG. 4, in a preferred embodiment, the swirl members 74 are configured such that the cooling fluid exiting the flow passage outlet 72 flows or moves in a direction D at an angle θ_D of from about 65° to about 85° relative to a central axis C_A (see FIGS. 1 and 4) of the engine 10. Such a flow direction D of the cooling fluid can be effected by forming the trailing edges 78 of the swirl members 74 so that they extend at an angle θ_{SM} of from about 65° to about 85° relative to the central axis C_A of the engine 10.

Further, the swirl members 74 in the preferred embodiment are circumferentially spaced from one another so as to allow a desired amount of cooling fluid through the flow passage 68 to adequately cool the structure to be cooled in the turbine section 13 of the engine 10. As shown in FIG. 4, the narrowest spacing S_P between the trailing edge 78 of one swirl member 74 and an adjacent swirl member 74, which spacing S_P may also be referred to as the throat section between the swirl members 74, is also preferably configured to obtain a desired pressure drop, i.e., caused by a Venturi effect effected by the converging sidewalls 75A and 75B of the swirl members 74, and to cause a corresponding velocity increase as the cooling fluid flows through the flow passage 68. According to one embodiment, the narrowest spacing S_P between the first sidewall 75A at the trailing edge 78 of one swirl member 74 and the second sidewall 75B of the adjacent swirl member 74 may be about 10 mm, but may vary depending upon the particular configuration of the engine 10. It is noted that the velocity component V^{TC} of the cooling fluid exiting the flow passage outlet 72 in the direction tangent to the circumferential direction is preferably greater than a velocity component of the shaft 22 and the rotor 16 in the direction tangent to the circumferential direction during operation of the engine 10, as will be discussed in greater detail herein.

Since the pre-swirl structure 30 is located close to the shaft 22, a leakage interface area between the pre-swirl structure 30

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and the shaft cover structure 20 is reduced, as compared to if the pre-swirl structure 30 were to be located further radially outwardly. Specifically, the leakage interface area between the pre-swirl structure 30 and the shaft cover structure 20 is defined as the area between where the radially inner wall structure 64 and the shaft cover structure 20 meet, in addition to the area between where the radially outer wall structure 66 and the shaft cover structure 20 come together. Since these areas are located generally close to the shaft 22, their circumferences are relatively small (as compared to if these areas were located radially outwardly further from the shaft 22), such that the leakage areas are relatively small. This is compared to a configuration where the leakage areas are radially outwardly further from the shaft 22, in which case the circumferences of the leakage interface areas would be larger. This same concept applies for leakage through first and second sealing structure 98 and 106, each of which will be discussed below.

An annular cavity 84 is located downstream from the pre-swirl structure 30 and extends from the flow passage outlet 72 to a plurality of bores 86 formed in the first blade disc structure 114. As illustrated in FIGS. 1-3, the annular cavity is substantially defined by the first blade disc structure 114, the pre-swirl structure 30, and a particle deflecting structure 90, which particle deflecting structure 90 will be described in detail herein. The bores 86 in the first blade disc structure 114 extend radially outwardly and axially downstream through the first blade disc structure 114 to the first row 14A of blades 14 to provide the first portion of cooling fluid to internal cooling circuits 14A₁ formed in the blades 14, see FIG. 1.

Referring back to FIGS. 2 and 3, a particle separator 89 according to an aspect of the present invention comprises the particle deflecting structure 90 and the particle collection chamber 34, which, as noted above, is defined by a portion of the shaft cover structure 20. The particle deflecting structure 90 is located in the annular cavity 84 downstream from the pre-swirl structure 30 and upstream from the bores 86 in the first blade disc structure 114. The particle deflecting structure 90 is coupled to and extends radially inwardly from a seal arm 92 of the first blade disc structure 114, and, thus, rotates with the first blade disc structure 114 and the rotor 16 during operation of the engine 10.

The particle deflecting structure 90 includes a radially inwardly extending portion 94 that extends radially inwardly from the seal arm 92 of the first blade disc structure 114 and a generally axially extending portion 96. The radially inwardly extending portion 94 includes a radially inner end portion 97, which end portion 97 is curved in the radial direction such that it extends in the axial direction at its end toward the pre-swirl structure 30 and the particle collection chamber 34. The end portion 97 is located further radially inwardly than the axially extending portion 96, which axially extending portion 96 extends generally axially from the radially extending portion 94 toward the pre-swirl structure 30 and the particle collection chamber 34. However, as most clearly seen in FIG. 6, the axially extending portion 96 is slightly sloped in the radial direction as it extends toward the pre-swirl structure 30 and the particle collection chamber 34, i.e., the axially extending portion 96 is sloped such that it expands circumferentially in a direction toward the particle collection chamber 34. As will be described in detail herein, the particle deflecting structure 90 deflects solid particles from the first portion of cooling fluid into the particle collection chamber 34 after the first portion of cooling fluid exits the pre-swirl structure 30.

Referring to FIGS. 2 and 3, the first sealing structure 98 is located radially outwardly from the annular cavity 84

between the shaft cover structure 20 and the axially extending portion 96 of the particle deflecting structure 90. The first sealing structure 98 is located axially between the flow passage outlet 72 and the bores 86 in the first blade disc structure 114. The first sealing structure 98 limits leakage between the annular cavity 84 and a turbine rim cavity 100, which turbine rim cavity 100 is defined by the first blade disc structure 114 and the first lower stator support structure 118 and is located proximate to the hot gas flow path HG. Additional details in connection with the turbine rim cavity 100 will be discussed in detail herein. The first sealing structure 98 may comprise, for example, one or more knife-edge seal members 102 extending radially outwardly from the axially extending portion 96 of the particle deflecting structure 90, and a honeycomb seal or abrasible material 104 associated with the shaft cover structure 20. It is noted that other types of sealing structure may be used.

Also shown in FIGS. 2 and 3, the second sealing structure 106 is employed between the shaft cover structure 20 and the shaft 22 proximate to the aft end portion 26 of the shaft cover structure 20. The second sealing structure 106 limits leakage between the annular cavity 84 and a shaft cover cavity 108, which shaft cover cavity 108 will be discussed in detail herein. The second sealing structure 106 may comprise, for example, one or more knife-edge seal members 110 extending radially outwardly from the shaft 22, and a honeycomb seal or abrasible material 112 associated with the shaft cover structure 20. It is noted that other types of sealing structure may be used.

Referring still to FIGS. 2 and 3, the shaft cover structure 20 at least partially defines the particle collection chamber 34, as noted above. The particle collection chamber 34 extends circumferentially about the shaft 22 and is in fluid communication with the annular cavity 84. The particle collection chamber 34 is located upstream of the particle deflecting structure 90 and at least partially radially outwardly from the annular cavity 84. As will be described in detail herein, the particle collection chamber 34 collects particles deflected from the first portion of cooling fluid by the particle deflecting structure 90. It is noted that some particles may flow directly into the particle collection chamber 34, i.e., without being deflected by the particle deflecting structure 90, as a result of the particles moving radially outwardly, as will be discussed herein.

Referring to FIGS. 1-3, the bypass passages 32 provide cooling fluid, including a second portion of cooling fluid from the cooling fluid chamber 50 to a metering structure 120, which metering structure 120 provides the second portion of cooling fluid from the bypass passages 32 into the turbine rim cavity 100.

The bypass passages 32 according to this aspect of the present invention comprise two types of passages. Specifically, a plurality of primary bypass passages 132 provide cooling fluid located in the shaft cover cavity 108 to the metering structure 120, wherein at least a portion of the cooling fluid located in the shaft cover cavity 108 is from the cooling fluid chamber 50. Further, a plurality of secondary bypass passages 134 provide cooling fluid located in the cooling fluid chamber 50 directly to the metering structure 120.

As noted above, at least a portion of the cooling fluid in the shaft cover cavity 108 that flows to the metering structure 120 through the primary bypass passages 132 comprises cooling fluid from the cooling fluid cavity 50. Specifically, cooling fluid flows from the cooling fluid cavity 50 through one or more cooling fluid ports 136 (see FIG. 1) formed in the forward end portion 24 of the shaft cover structure 20. A

portion of this cooling fluid leaks through the shaft seal assembly 28 into the shaft cover cavity 108, and then flows to the metering structure 120 via the primary bypass passages 132.

Additional cooling fluid in the shaft cover cavity 108 may enter the shaft cover cavity 108 from the annular cavity 84 by leaking through the second sealing structure 106. It is noted that cooling fluid preferably does not leak from the shaft cover cavity 108 into the annular cavity 84, as the pressure of the cooling fluid in the annular cavity 84 is preferably as high as or higher than the pressure of the cooling fluid located within the shaft cover cavity 108.

The primary bypass passages 132 in the embodiment shown extend radially outwardly and axially downstream from where they communicate with the shaft cover cavity 108 to a location L_P (see FIG. 2) and then extend generally axially downstream to the metering structure 120. The radially and axially extending sections of the primary bypass passages 132 do not communicate with the pre-swirl passages 60, such that the cooling fluid in the primary bypass passages 132 does not interact with the first portion of cooling fluid flowing through the pre-swirl passages 60 to the pre-swirl structure 30. This is accomplished in the embodiment shown by forming the primary bypass passages 132 through the shaft cover structure 20 at different circumferential locations than the pre-swirl passages 60.

The secondary bypass passages 134 extend generally axially downstream from the cooling fluid chamber 50 to the metering structure 120, as shown in FIGS. 2 and 3. The secondary bypass passages 134 do not communicate with the pre-swirl passages 60, such that the cooling fluid in the secondary bypass passages 134 does not interact with the first portion of cooling fluid flowing in the pre-swirl passages 60 to the pre-swirl structure 30. This is accomplished in the embodiment shown by forming the secondary bypass passages 134 through the shaft cover structure 20 at different circumferential locations than the pre-swirl passages 60. It is noted that the secondary bypass passages 134 are also formed through the shaft cover structure 20 at different circumferential locations than the primary bypass passages 132, such that the cooling fluid flowing in the secondary bypass passages 134 does not interact with the cooling fluid flowing in the primary bypass passages 132.

According to an aspect of the invention, the ratio of primary bypass passages 132 to secondary bypass passages 134 may be, for example, about 3 to 1. According to the embodiment shown, the number of primary bypass passages 132 is 18 and the number of secondary bypass passages 134 is 6.

The metering structure 120 according to the embodiment shown comprises a ring-shaped metering member, shown in FIG. 5, which extends circumferentially about the shaft 22 and is received in a corresponding circumferentially extending slot 138 formed in the aft end portion 26 of the shaft cover structure 20, see FIGS. 2 and 3.

As shown in FIG. 5, the metering structure 120 comprises a plurality of first and second flow passageways 140 and 142 formed therein. The flow passageways 140 and 142 extend through the metering structure 120 and provide fluid communication between the bypass passages 32 and the turbine rim cavity 100. Specifically, the first flow passageways 140 provide fluid communication between outlets 132A of the primary bypass passages 132 (see FIGS. 2, 3, and 5) and the turbine rim cavity 100, while the second flow passageways 142 provide fluid communication between outlets 134A of the secondary bypass passages 134 (see FIGS. 2, 3, and 5) and the turbine rim cavity 100. As shown in FIG. 5, the number of first flow passageways 140 to the number of second flow

passageways **142** in the embodiment shown correspond to the number of primary bypass passages **132** and secondary bypass passages **134**, i.e., 18 first flow passageways **140** and 6 second flow passageways **142** are provided in the metering structure **120** in the embodiment shown. However, it is noted that extra bypass passages **32**, i.e., primary and/or secondary bypass passages **132**, **134**, may be formed in the shaft cover structure **20** in case it is desirable to subsequently form additional flow passageways **140** and/or **142** in the metering structure **120**. This may be desirable for a situation where additional cooling fluid flow into the turbine rim cavity **100** is sought. If this is the case, additional flow passageways **140** and/or **142** could be formed in the metering structure **120** at the locations of the previously blocked outlets **132A**, **134A** of the respective bypass passages **132**, **134** to allow additional cooling fluid to flow through those bypass passages **132**, **134** and corresponding flow passageways **140**, **142** into the turbine rim cavity **100**.

Each flow passageway **140**, **142** is formed in the metering structure **120** at an angle relative to the central axis C_A of the engine **10**, such that cooling fluid flowing out of each flow passageway **140**, **142** has a velocity component in the direction tangential to the circumferential direction. According to the preferred embodiment, each flow passageway **140**, **142** is formed at an angle of at least about 70° relative to the central axis C_A of the engine **10**.

Further, each flow passageway **140**, **142** has a diameter D_{FP} (see FIG. 5) that is no larger than about half the size of a diameter D_{BP} (see FIG. 2) of a corresponding one of the bypass passages **132**, **134**. Thus, if it is desirable to increase the amount of cooling fluid that passes through the metering structure **120** from the bypass passages **32** into the turbine rim cavity **100**, the diameters D_{FP} of select ones or all of the flow passageways **140**, **142** can be increased to accommodate the increased flow volume. Alternatively, if it is desirable to decrease the amount of cooling fluid that passes through the metering structure **120** from the bypass passages **32** into the turbine rim cavity **100**, one or more of the passageways **140**, **142** could be blocked such that cooling fluid does not enter the turbine rim cavity **100** through the blocked passageways **140**, **142**.

Since the diameters D_{BP} of the bypass passages **32** are larger than the diameters D_{FP} of the flow passageways **140**, **142**, the bypass passages **32** can accommodate the additional flow volume without being altered. It is noted that the diameters D_{BP} of the bypass passages **32** and the diameters D_{FP} of the flow passageways **140**, **142** are sized so as to provide a sufficient amount of cooling fluid into the turbine rim cavity **100** from the flow passageways **140**, **142** to adequately cool the first blade disc structure **114** and the first lower stator support structure **118** and to reduce or prevent hot combustion gas ingestion into the turbine rim cavity **100** from the hot gas flow path HG. That is, a sufficient amount of cooling fluid is provided into the turbine rim cavity **100** to maintain the pressure within the turbine rim cavity **100** at a level wherein leakage of hot combustion gases from the hot gas flow path HG into the turbine rim cavity **100** is substantially prevented. However, in the preferred embodiment, the diameters D_{BP} of the bypass passages **32** and the diameters D_{FP} of the flow passageways **140**, **142** are sized so as to limit the amount of cooling fluid provided to the turbine rim cavity **100**; hence, maintaining the pressure within the turbine rim cavity **100** below the pressure within the annular cavity **84** and not providing more cooling fluid into the turbine rim cavity **100** than is needed. Thus, any leakage between the turbine rim cavity **100** and the annular cavity **84** through the first sealing structure **98** is from the annular cavity **84** into the turbine rim

cavity **100**. This is preferable, as cooling fluid leaking from the turbine rim cavity **100** into the annular cavity **84** could reduce the velocity component V_{TC} of the first portion of cooling fluid flowing into the bores **86** in the first blade disc structure **114**, which is undesirable.

During operation of the engine **10**, compressed air from the compressor section **11** is provided to the combustion section **12** and is burned with fuel to create hot working gases as discussed above. The hot working gases from the combustion section **12** are directed into and through the transition ducts **12A** and are released into the turbine section **13**. The working gases flow through the hot gas path HG in the turbine section **13** where the working gases are expanded and cause the blades **14** and blade disc structures to rotate to effect rotation of the rotor **16** and the shaft **22**.

Cooling fluid, e.g., compressor bleed air that may be cooled in an external cooler, enters the cooling fluid chamber **50** via the cooling fluid feed tubes **52**, see FIG. 1. A first portion of the cooling fluid flows to the pre-swirl structure **30** through the pre-swirl passages **60**, wherein the first portion of cooling fluid flows through the flow passage **68** of the pre-swirl structure **30**.

As the first portion of cooling fluid passes through the flow passage **68** of the pre-swirl structure **30**, the swirl members **74** provide to the cooling fluid a velocity component V_{TC} in the direction tangential to the circumferential direction, as discussed above. This tangential velocity component V_{TC} of the first portion of cooling fluid as the first portion of cooling fluid exits the flow passage outlet **72** is such that a swirl ratio, which is defined as the velocity component V_{TC} of the cooling fluid in the direction tangential to the circumferential direction to a velocity component of the shaft **22** in the direction tangential to the circumferential direction, is greater than one. In a preferred embodiment for the engine **10** illustrated herein, as the cooling fluid passes out of the pre-swirl structure **30**, the swirl ratio is preferably between about 1.15 and about 1.25. It is noted that the desired swirl ratio of the cooling fluid passing out of the pre-swirl structure **30** may vary depending on the particular engine in which the pre-swirl structure **30** is employed. For example, for some types of engines, this swirl ratio may be as high as about 3. In FIG. 6, swirl ratios of the cooling fluid at relevant sections of the engine **10** are illustrated.

The cooling fluid passing out of the pre-swirl structure **30** enters the annular cavity **84**, where the first portion of cooling fluid flows circumferentially, i.e., due to passing through the pre-swirl structure **30**, and also flows axially downstream toward the bores **86** formed in the first blade disc structure **114**. It is noted that the downstream flow of the cooling fluid is caused by the pressure in the internal cooling circuits **14A**, formed in the blades **14** being lower than both the pressure of the cooling fluid in the cooling fluid chamber **50** and the pressure of the cooling fluid in the annular cavity **84**.

The axial flow of the first portion of cooling fluid through the annular cavity **84** is desirable to allow for particles to flow to the radially outer portion of the annular cavity **84**, such that the particles can be removed from the first portion of cooling fluid by the particle separator **89**. Specifically, as the first portion of cooling fluid flows circumferentially in the annular cavity **84**, solid particles, such as rust particles, sand, etc., which may be carried with the first portion of cooling fluid, flow radially outwardly to the radially outer portion of the annular cavity **84**. This radially outer flow of the solid particles is caused by centrifugal forces that act on the particles, which have more mass and therefore more momentum than the cooling fluid with which the particles are flowing.

Since the solid particles are caused to flow to the radially outer portion of the annular cavity **84**, some of the particles flow directly into the particle collection chamber **34**. Other particles flow axially through the annular cavity **84** and contact the radially inwardly extending portion **94** of the particle deflecting structure **90**. Upon contacting the radially inwardly extending portion **94** of the particle deflecting structure **90**, the particles are deflected thereby and flow axially upstream along the slight radial slope of the axially extending portion **96** of the particle deflecting structure **90** toward the particle collection chamber **34**. It is noted that the tendency for the particles to flow upstream may be caused, at least in part, by the slight radial slope of the axially extending portion **96** and the centrifugal forces acting on the particles that cause the particles to flow radially outwardly, i.e., caused by their mass.

The majority of the solid particles deflected by the particle deflecting structure **90** are collected in the particle collection chamber **34**, where they can be removed therefrom, for example, during maintenance of the engine **10**. However, it is noted that a small amount of the particles may flow through the first sealing structure **98** into the turbine rim cavity **100**. It is believed that these particles may eventually pass into the hot gas flow path **HG**, where they may be burned off by the hot combustion gases or carried along the hot gas path **HG** with the combustion gases. It is also noted that some small particles may not have enough mass to flow to the radially outer portion of the annular cavity **84**. These small particles may flow with the cooling fluid into the bores **86** in the first blade disc structure **114**. However, most of the larger particles are believed to be separated and removed from the cooling fluid by the particle separator **89**.

It is noted that an axial flow distance A_F (see FIG. 6) of the first portion of cooling fluid within the annular cavity **84** in the engine **10** illustrated herein is greater than a radial flow distance R_F (see FIG. 6) of the first portion of cooling fluid within the annular cavity **84** as the first portion of cooling fluid flows from the flow passage outlet **72** to the bores **86** formed in the first blade disc structure **114**. In the engine **10** illustrated herein, the radial flow distance R_F of the first portion of cooling fluid within the annular cavity **84** is about $\frac{2}{3}$ of the axial flow distance A_F of the first portion of cooling fluid within the annular cavity **84**, e.g., the axial flow distance A_F may be about 97 mm, and the radial flow distance R_F may be about 62 mm. According to one embodiment, the axial flow distance A_F may be at least about 50 mm, which distance is believed to allow for most of the solid particles to be removed from the first portion of the cooling fluid by the particle separator **89**. Specifically, since the particle deflecting structure **90** is located axially close to the bores **86**, the first portion of cooling fluid swirls a sufficient amount in the annular cavity **84** to cause the majority of the solid particles to move to the radially outer portion of the annular cavity **84**, such that the particles can be separated from the first portion of the cooling fluid by the particle separator **89**, as discussed above. According to another embodiment, the axial flow distance A_F may be at least about 75 mm, such that more of the particles can be removed from the first portion of cooling fluid.

As shown in FIG. 6, once the first portion of cooling fluid traverses the axial flow distance A_F of the annular cavity **84** and solid particles are removed by the particle separator **89**, the cooling fluid flows into a free vortex portion **84A** of the annular cavity **84**, where the cooling fluid flows radially outwardly in the free vortex portion **84A** towards the bores **86** in the first blade disc structure **114**. As the first portion of cooling fluid flows radially outwardly into the bores **86**, the velocity component V_{TC} of the cooling fluid in the direction tangential to the circumferential direction decreases, due to a

free vortex or inviscid behavior, such that the velocity component V_{TC} of the cooling fluid preferably becomes approximately equal to that of the shaft **22** and the rotor **16**. That is, the swirl ratio just before the cooling fluid enters the bores **86** is about 1 (see FIG. 6). This reduction in the velocity component V_{TC} is caused by free vortex behavior as a result of the angular momentum of the first portion of cooling fluid dominating the angular momentum of the rotor drag in a near inviscid fashion. In this area, i.e., in the free vortex portion **84A** of the annular cavity **84**, angular momentum of the rotor **16** is constant.

The velocity component V_{TC} decrease of the first portion of cooling fluid causes a corresponding static pressure increase of the cooling fluid, which is obtained free of any transfer or work, i.e., of the rotor **16** on the first portion of cooling fluid, and is non parasitic. The pressure of the cooling fluid is preferably increased to a pressure that is greater than the pressure of the hot combustion gases flowing through the hot gas flow path **HG** due to both a free vortex static pressure increase resulting from the decrease in the velocity component V_{TC} and a forced vortex total pressure increase in the bores **86** resulting from the rotation of the bores **86**. Hence, hot gas ingestion into the internal cooling circuits **14A₁** formed in the blades **14** is substantially avoided. It is noted that it may be desirable for the pressure of the cooling fluid as it enters the bores **86** in the first blade disc structure **114** to be equal to a preset value defined by the engine manufacturer for a given engine to ensure that the pressure of the cooling fluid entering the bores **86** is slightly greater than the pressure of the hot combustion gases flowing through the hot gas flow path **HG**.

It is noted that, since the bores **86** extend radially outwardly as the cooling fluid passes therethrough, the cooling fluid is caused to move at the same rotational speed as the first blade disc structure **114**, i.e., such that the swirl ratio is equal to 1 as the cooling fluid flows within the bores **86**. Since the first portion of cooling fluid and the first blade disc structure **114** include generally the same velocity component in the direction tangential to the circumferential direction just prior to the cooling fluid entering the bores **86**, i.e. the swirl ratio is about 1 just prior to the cooling fluid entering the bores **86**, the rotor **16** is not required to increase the velocity component V_{TC} of the cooling fluid up to that of the first blade disc structure **114**. This is desirable, because if the velocity component V_{TC} of the cooling fluid were to be increased by the rotor **16**, a corresponding pressure drop and temperature increase would result from the velocity increase. The temperature increase would result in an increase in the temperature of the first portion of cooling fluid flowing into the bores **86**. Such a temperature increase is undesirable, as it would adversely affect cooling of the blades **14** and the other structure to be cooled within the turbine section **13**. Further, by decreasing or avoiding the pressure drop of the first portion of cooling fluid as it enters the bores **86**, an increased pressure drop is achieved as the first portion of cooling fluid passes through the pre-swirl structure **30**. Thus, a corresponding velocity component V_{TC} increase of the cooling fluid, i.e., due to the pressure drop increase, is increased as the first portion of cooling fluid passes through the pre-swirl structure **30**.

Additionally, since the rotor **16** is not required to increase the velocity component V_{TC} of the cooling fluid up to that of the first blade disc structure **114** prior to the cooling fluid entering the bores **86**, the rotor **16** is not required to expend any work that would otherwise be required to increase the velocity component V_{TC} of the cooling fluid up to the same velocity component as the first blade disc structure **114** as the cooling fluid enters the bores **86**. Hence, work expended to

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rotate the rotor/shaft is believed to be conserved, which increases the efficiency and output of the engine 10. Further, the conservation of the rotor work may result in an increase in the rotating velocity of the rotor/shaft and/or a reduction in the amount of fuel required to rotate the rotor/shaft. It is noted that some work must be done by the rotor 16 to maintain the swirl ratio at 1 as the first portion of cooling fluid flows radially outwardly in the bores 86. However, the work saved by the rotor 16 not being required to increase the velocity component V_{TC} of the cooling fluid up to the same velocity component as the first blade disc structure 114 as the cooling fluid enters the bores 86 results in the benefits discussed above.

It is also noted that, this conserving of rotor work is also believed to avoid an increase in the temperature of the cooling fluid that would otherwise be associated with the rotor 16 expending the work to increase the velocity component V_{TC} of the cooling fluid up to the same velocity component as the first blade disc structure 114 as the cooling fluid enters the bores 86. That is, if the rotor 16 were required to increase the velocity component V_{TC} of the cooling fluid as the cooling fluid enters the bores 86, the work done by the rotor 16 would heat up the cooling fluid entering the bores 86, i.e., caused by a combination of Euler work and/or windage forces or friction forces. However, since this work of the rotor 16 to increase the velocity component V_{TC} of the cooling fluid is not needed, the temperature increase of the cooling fluid associated with the work is avoided. Hence, the cooling fluid flowing into the cooling fluid chamber 50 need not be as cool as in a situation where the cooling fluid would otherwise be heated by the Euler work and/or windage forces or friction forces.

Moreover, since the majority of the solid particles in the first portion of cooling fluid are deflected by the particle deflecting structure 90 and captured in the particle collection chamber 34, particle flow into the bores 86 and into the internal cooling circuits 14A₁ formed in the blades 14 downstream from the bores 86 is reduced. Reducing the number of particles and the sizes of the particles that enter bores 86 and the internal cooling circuits 14A₁ formed in the blades 14 is believed to improve cooling to the blades 14, as particles (especially large particles) can clog or otherwise block cooling passages and/or cooling holes that deliver the cooling fluid to the blades 14 and other structure to be cooled by the cooling fluid. Since these cooling passages and/or cooling holes are not likely to be blocked by particles, i.e., since the particles are separated from the cooling fluid by the particle separator 89, these cooling passages and/or cooling holes may be designed to have smaller diameters than in prior art engines. This is because diameters of cooling passages and/or cooling holes in prior art engines are typically designed so as to tolerate particles to be conveyed therethrough along with the cooling fluid. If the cooling passages and/or cooling holes can be designed to have smaller diameters, a lesser amount of cooling air may be supplied from the cooling fluid chamber 50 while still providing adequate cooling to the components to be cooled in the turbine section 13.

A second portion of cooling fluid flows through the bypass passages 32 to the metering structure 120, which conveys the second portion of cooling fluid into the turbine rim cavity 100. As discussed above, some of the second portion of cooling fluid passes to the metering structure 120 through the primary bypass passages 132, and some of the second portion of cooling fluid flows to the metering structure 120 through the secondary bypass passages 134. As noted above, the second portion of cooling fluid flowing to the metering structure

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120 does not interact with the first portion of cooling fluid flowing through the pre-swirl passages 60 to the pre-swirl structure 30.

Since the flow passageways 140, 142 formed in the metering structure 120 are angled relative to horizontal, the second portion of cooling fluid flowing into the turbine rim cavity 100 from the metering structure 120 includes a velocity component in the direction tangential to the circumferential direction in the same direction as the rotor 16 and the shaft 22 rotate. Thus, the second portion of cooling fluid entering the turbine rim cavity 100 from the metering structure 120 does not slow down the rotor 16, i.e., due to windage forces, which is believed to further increase the efficiency of the engine 10.

Referring now to FIG. 7, a portion of a gas turbine engine 210 according to another embodiment of the invention is shown. The engine 210 includes a central axis C_{A1} defining an axial direction of the engine 210. The engine 210 comprises a conventional compressor section 211, a combustion section 212, and a turbine section 213 as discussed above with reference to the engine 10. A plurality blade disc structures, including a first blade disc structure 214, are positioned adjacent to one another in the axial direction so as to define a rotor 216, and a plurality of vane assemblies, including a first row vane assembly 218, are positioned adjacent to one another in the axial direction between respective blade disc structures, as discussed above.

As shown in FIG. 7, a shaft cover structure 220 surrounds a portion of a shaft 222, which shaft 222 is coupled to the rotor 216 for rotation with the rotor 216. The shaft cover structure 220 according to this embodiment comprises an outer shaft cover 224, also referred to herein with respect to FIGS. 1-6 as an "outer cover", and an inner shaft cover 226, also referred to herein with respect to FIGS. 1-6 as a "shaft cover structure". It is noted that the shaft cover structure 220 does not rotate with the shaft 222 during operation of the engine 210.

The outer shaft cover 224 is located radially outwardly from the inner shaft cover 226 and cooperates with the inner shaft cover 226 to define a cooling fluid chamber 228 therebetween. The cooling fluid chamber 228 receives cooling fluid from a supply of cooling fluid as discussed above with respect to FIGS. 1-6. The outer shaft cover 224 is structurally supported by a main engine casing (not shown) via a plurality of struts (not shown) extending from the main engine casing to the outer shaft cover 224. The outer shaft cover 224 comprises a generally cylindrical member having a forward end portion 230 and an opposed aft end portion 232.

The inner shaft cover 226 comprises a generally cylindrical member having a forward end portion 234 and an opposed aft end portion 236. The inner shaft cover 226 is structurally supported by the outer shaft cover 224 via a first seal structure 238 located adjacent to the forward end portions 230 and 234 of the outer and inner shaft covers 224 and 226. The first seal structure 238 also creates a substantially fluid tight seal between the forward end portions 230 and 234 of the outer and inner shaft covers 224 and 226. Second seal structure 240, such as, for example, a dog bone seal or diaphragm seal, is disposed between the aft end portion 232 of the outer shaft cover 224 and the aft end portion 236 of the inner shaft cover 226 for creating a substantially fluid tight seal therebetween.

As shown in FIG. 7, an air separator structure 242 is located between the shaft 222 and the inner shaft cover 226. The air separator structure 242 comprises a generally cylindrical member and is coupled to and rotates with the shaft 222 during operation of the engine 210. The air separator structure 242 includes a first axially extending portion 242A, a second axially extending portion 242 downstream from the first axially extending portion 242A, and an air separator portion

242C downstream from the second axially extending portion 242B. A plurality of spanning members 246 (one shown in FIG. 7) extend between the first and second axially extending portions 242A and 242B, which spanning members 246 define a plurality of openings 248 therebetween, which openings 248 will be discussed further below. The spanning members 246 provide structural support for the second axially extending portion 242B and the air separator portion 242C via the first axially extending portion 242A, which first axially extending portion 242A is coupled to the shaft 222 at the location L_S .

Referring additionally to FIG. 8, a first portion of cooling fluid supplied by the cooling fluid chamber 228 flows radially inwardly through a series of inlet openings 250 formed in the inner shaft cover 226. The inlet openings 250 are defined by a plurality of circumferentially spaced apart inner shaft cover struts 252 that extend axially between a first axially extending portion 226A of the inner shaft cover 226 and a second axially extending portion 226B of the inner shaft cover 226 downstream from the first axially extending portion 226A (FIG. 7). The first portion of cooling fluid passes through the inlet openings 250 to a pre-swirl structure 256 according to this aspect of the invention.

As shown in FIG. 7, the pre-swirl structure 256 includes a forward wall structure 258 that extends circumferentially about the shaft 222 and is coupled to the first axially extending portion 226A of inner shaft cover 226. The pre-swirl structure 256 also includes an aft wall structure 260 axially spaced from the forward wall structure 258. The aft wall structure 260 extends circumferentially about the shaft 222 and is coupled to the second axially extending portion 226B of inner shaft cover 226. The forward and aft wall structures 258 and 260 define an annular flow passage 262 therebetween, which flow passage 262 includes an inlet 264 and an outlet 266 (see also FIGS. 8 and 8A), through which the first portion of cooling fluid passes after entering the pre-swirl structure 256 from the cooling fluid chamber 228, as will be described herein.

As shown in FIGS. 7, 8, and 8A a plurality of swirl members 268 extend in the flow passage 262. The swirl members 268 span between the forward and aft wall structures 258, 260. As shown in FIG. 8A, the swirl members 268 each include opposed first and second sidewalls 270, 272, a leading edge 274 proximate to the flow passage inlet 264, and a trailing edge 276 proximate to the flow passage outlet 266. In a preferred embodiment, the leading edges 274 of the swirl members 268 are circumferentially aligned with respective ones of the inner shaft cover struts 252 such that the inner shaft cover struts 252 do not block cooling fluid attempting to pass to the pre-swirl structure 256. That is, since the leading edges 274 of the swirl members 268 are circumferentially aligned with the inner shaft cover struts 252, a direct radial path is provided through the inlet openings 250 for the first portion of cooling fluid to flow from the cooling fluid chamber 228 to the pre-swirl structure 256.

The leading edge 274 of each of the swirl members 268 is offset from the trailing edge 276 in a circumferential direction, as shown in FIGS. 8 and 8A. Thus, a flow direction of the first portion of cooling fluid flowing through the flow passage 262 is altered by the swirl members 268, such that the first portion of cooling fluid exiting the flow passage outlet 266 has a velocity vector V_1 (see FIG. 8A) with a velocity component V_{TC1} in a direction tangent to the circumferential direction, and a radial velocity component V_R as the first portion of cooling fluid flows out of the flow passage outlet 266. An angle Ω between the velocity vector V_1 and its velocity component V_R may be between about 75° and about 85° .

It is noted that the velocity component V_{TC1} of the first portion of cooling fluid exiting the flow passage outlet 266 in the direction tangent to the circumferential direction is preferably substantially the same as a velocity component of the shaft 222 and the rotor 216 in the direction tangent to the circumferential direction during operation of the engine 210.

Referring to FIG. 8A, in a preferred embodiment, the swirl members 268 are configured such that the cooling fluid exiting the flow passage outlet 266 flows or moves in a direction D_2 at an angle Ω_D of from about 75° to about 85° relative to a radial axis R_A (see FIGS. 7 and 8) of the engine 210. Such a flow direction D_2 of the cooling fluid can be effected by forming the trailing edges 276 of the swirl members 268 so that they extend at an angle Ω_{SM} of from about 75° to about 85° relative to the radial axis R_A of the engine 210.

Further, as shown in FIG. 8A, the swirl members 268 in the preferred embodiment are circumferentially spaced apart from one another so as to allow a desired amount of cooling fluid through the flow passage 262 to adequately cool structure to be cooled in the turbine section 213 of the engine 210, as will be discussed herein. The narrowest spacing S_{P1} between the trailing edge 276 of one swirl member 268 and the second sidewall 272 of an adjacent swirl member 268, which spacing S_{P1} may also be referred to as the throat section between the swirl members 268, is also preferably configured to obtain a desired pressure drop, i.e., caused by a Venturi effect effected by the converging sidewalls 270 and 272 of the swirl members 268, and to cause a corresponding velocity increase as the cooling fluid flows through the flow passage 262. According to one embodiment, the narrowest spacing S_{P1} between the first sidewall 270 at the trailing edge 276 of one swirl member 268 and the second sidewall 272 of the adjacent swirl member 268 may be about 10 mm, but may vary depending upon the particular configuration of the engine 210. An axial length L_1 (see FIG. 7) of each of the swirl members 268 according to an exemplary embodiment of the invention may be about 15-25 mm and a chordal height H_1 (see FIG. 8A) of each of the swirl members 268 according to an exemplary embodiment of the invention may be about 60-105 mm.

Referring back to FIG. 7, the first portion of cooling fluid exits the flow passage 262, passes through the openings 248 in the air separator structure 242, and enters a flow path 280 located between the shaft 222 and the shaft cover structure 220, i.e., between the air separator structure 242 and the shaft 222 in the embodiment shown. The flow path 280 extends generally in the axial direction between the air separator structure 242 and the shaft 222 and provides fluid communication between the pre-swirl structure 256 and a plurality of bores 282 formed in the first blade disc structure 214.

First ones 282A of the bores 282 in the first blade disc structure 214 extend radially outwardly through the first blade disc structure 214 to provide a first allocation of the first portion of cooling fluid to blades of the first blade disc structure 214, which blades were described above with respect to FIGS. 1-6. Second ones 282B of the bores 282 are provided as a pathway for a second allocation of the first portion of cooling fluid to remaining blade disc structures in the turbine section 213 of the engine 210.

As shown in FIG. 7, a plurality of bypass passages 290 (one shown in FIG. 7) provide a second portion of cooling fluid, which may include a small amount of the first portion of cooling fluid (as will be described herein) to a metering structure 292 located at exit openings 290A of the bypass passages 290 at an end 296 of the inner shaft cover 226. The metering structure 292 provides the second portion of cooling fluid

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from the bypass passages 290 into a turbine rim cavity 294, which turbine rim cavity 294 was described above with respect to FIGS. 1-6.

The bypass passages 290 according to this aspect of the invention comprise inlet openings 298 formed in a radially inner surface 300 of the first axially extending portion 226A of the inner shaft cover 226. The bypass passages 290 extend radially outwardly and axially downstream from the inlet openings 298 through the inner shaft cover 226 to a location L_{P1} and then extend generally axially downstream through the inner shaft cover 226 to the metering structure 292 located at the exit openings 290A.

The bypass passages 290 do not communicate with the inlet openings 250 in the inner shaft cover 226 or with the flow passage 262 or the flow path 280, such that the second portion of cooling fluid in the bypass passages 290 does not interact with the first portion of cooling fluid flowing into and through pre-swirl structure 256 and into the flow path 280. This is accomplished in the embodiment shown by forming a portion of the bypass passages 290 through the inner shaft cover struts 252 (see also FIGS. 8 and 8A). It is noted that the number of inner shaft cover struts 252 having bypass passages 290 passing therethrough may vary depending on the amount of cooling fluid that is desirable to be provided into the turbine rim cavity 294. However, at least some of the inner shaft cover struts 252 preferably do not include bypass passages 290 passing therethrough, as shown in FIG. 7, so as to preserve the structural rigidity of the inner shaft cover 226.

The metering structure 292 according to this aspect of the invention may comprise a ring-shaped metering member, as discussed above with respect to FIGS. 1-6 and as shown in FIG. 5. The metering structure 292 comprises a plurality flow passageways 306 formed therein, which flow passageways 306 extend through the metering structure 292 and provide fluid communication between the bypass passages 290 and the turbine rim cavity 294. As discussed above with reference to FIGS. 1-6, each flow passageway 306 is preferably formed in the metering structure 292 at an angle relative to the central axis C_{A1} of the engine 210, such that cooling fluid flowing out of each flow passageway 306 has a velocity component in the direction tangential to the circumferential direction. According to the preferred embodiment, each flow passageway 306 is formed at an angle of at least about 70° relative to the central axis C_{A1} of the engine 210.

Remaining structure of the metering structure 292 is substantially similar to the metering structure 120 described above with reference to FIGS. 1-6, with the exception of the metering structure 292 according to this embodiment only comprising one type of flow passageway 306 since only one type of bypass passage 290 is provided in this embodiment.

As shown in FIG. 7, the forward end portion 234 of the inner shaft cover 226 includes a plurality of cooling fluid ports 308 formed therein (only one cooling fluid port 308 is shown in FIG. 7). A main amount of the second portion of cooling fluid passes through the cooling fluid ports 308 on its way to the bypass passages 290, as will be discussed herein. Further, a third portion of cooling fluid flows through the cooling fluid ports 308. The third portion of cooling fluid is provided to a chamber 310 in communication with the compressor section 211 of the engine 210 to provide cooling to structure to be cooled in the compressor section 211, such as, for example, conventional compressor discs (not shown).

The main amount of the second portion of cooling fluid passes through a seal member 312 located radially between the first axially extending portion 242A of the air separator structure 242 and the first axially ending portion 226A of the inner shaft cover 226 and located axially between an end

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surface 314 of the inner shaft cover 226 and the bypass passages 290. The seal member 312 may comprise for example, a rotating structure, such as a knife edge seal, coupled to the air separator structure 242, which may be in combination with a non-rotating seal structure, such as a honeycomb seal or an abradable material, coupled to the inner shaft cover 226. Other suitable exemplary types of first seal members include leaf seals, brush seals, and non-contacting fin seals. While the seal member 312 prevents substantial leakage between the first axially extending portion 242A of the air separator structure 242 and the first axially ending portion 226A of the inner shaft cover 226, the main amount of the second portion of cooling fluid passes through the cooling fluid ports 308 and through the seal member 312 on its way to the bypass passages 290 since a pressure at the bypass passages 290 is less than a pressure in the cooling fluid chamber 228.

As noted above, the second portion of cooling fluid may include a small amount of the first portion of cooling fluid. Specifically, a small amount of the first portion of cooling fluid may leak through a first sealing structure 316 located radially between the first axially extending portion 242A of the air separator structure 242 and the first axially ending portion 226A of the inner shaft cover 226 and located axially between the bypass passages 290 and the pre-swirl structure 256. The first sealing structure 316 may comprise for example, a rotating structure, such as a knife edge seal, coupled to the air separator structure 242, which may be in combination with a non-rotating seal structure, such as a honeycomb seal or an abradable material, coupled to the inner shaft cover 226. Other suitable exemplary types of first sealing structures include leaf seals, brush seals, and non-contacting fin seals. While the first sealing structure 316 prevents a substantial amount of cooling fluid exiting the pre-swirl structure 256 via the flow passage outlet 266 from entering the bypass passages 290, a small amount of the first portion of cooling fluid passing from the pre-swirl structure 256 into the flow path 280 may leak through the first sealing structure 316 since the pressure at the bypass passages 290 is less than the pressure of the first portion of cooling fluid as it exits the pre-swirl structure 256.

Referring still to FIG. 7, a second sealing structure 318 is located radially between the second axially extending portion 242B of the air separator structure 242 and the second axially extending portion 226B of the inner shaft cover 226 and is located axially between the pre-swirl structure 256 and the turbine rim cavity 294. The second sealing structure 318 may comprise for example, a rotating structure, such as a knife edge seal, coupled to the air separator structure 242, which may be in combination with a non-rotating seal structure, such as a honeycomb seal or an abradable material, coupled to the inner shaft cover 226. Other suitable exemplary types of second sealing structures include leaf seals, brush seals, and non-contacting fin seals. While the second sealing structure 318 prevents a substantial amount of cooling fluid exiting the pre-swirl structure 256 via the flow passage outlet 266 from entering the turbine rim cavity 294, a small amount of the first portion of cooling fluid may leak through the second sealing structure 318 since the pressure at the turbine rim cavity 294 is less than the pressure of the first portion of cooling fluid as it exits the pre-swirl structure 256.

During operation of the engine 210 the first portion of the cooling fluid flows to the pre-swirl structure 256 through the inlet openings 250 in the inner shaft cover 226. The first portion of cooling fluid passes through the flow passage 262 of the pre-swirl structure 256 and the swirl members 268

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provide a velocity component V_{TC1} to the cooling fluid in the direction tangential to the circumferential direction, as discussed above.

The first portion of cooling fluid passing out of the pre-swirl structure **256** passes through the openings **248** and enters the flow path **280**, where the first portion of cooling fluid flows circumferentially, i.e., due to passing through the pre-swirl structure **256**, and also flows axially downstream toward the bores **282** formed in the first blade disc structure **214**. The axial flow of the first portion of cooling fluid through the flow path **280** is desirable to allow for the velocity component V_{TC1} of the first portion of cooling fluid in the circumferential direction to substantially match that of the shaft **222** and the air separator structure **242**, which is coupled to the shaft **222**.

Once the first portion of cooling fluid traverses an axial flow distance A_{F1} of the flow path **280**, the second allocation of the first portion of cooling fluid enters the second ones **282B** of the bores **282** and is provided to remaining blade disc structures in the turbine section **213** of the engine **210**. The first allocation of the first portion of cooling fluid flows into a free vortex portion **320** of an annular cavity **322**, see FIG. 7. Details in connection with the flow of the first allocation of the cooling fluid in the free vortex portion **320** of the annular cavity **322** are disclosed above with respect to FIGS. 1-6. It is noted that the annular cavity **322** in the embodiment shown in FIG. 7 is separated from the second portion of cooling fluid on its way to the turbine rim cavity **294** by the air separator portion **242C** of the air separator structure **242**.

Also during operation of the engine **210**, the second portion of cooling fluid flows through the bypass passages **290** to the metering structure **292**, which metering structure **292** conveys the second portion of cooling fluid into the turbine rim cavity **294**, as discussed above. Further, the third portion of cooling fluid is provided into the chamber **310** to cool the structure to be cooled in the compressor section **211** of the engine **210**.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

What is claimed is:

1. A gas turbine engine having a central axis defining an axial direction comprising:

a supply of cooling fluid;

a rotatable shaft extending in the axial direction of the engine;

shaft cover structure disposed about said shaft such that a flow path extends in the axial direction between said shaft and said shaft cover structure;

pre-swirl structure coupled to said shaft cover structure and located radially between said supply of cooling fluid and said flow path, said pre-swirl structure extending in a circumferential direction about said shaft, said pre-swirl structure comprising:

forward wall structure;

aft wall structure spaced in the axial direction from said forward wall structure, said forward and aft wall structures defining a flow passage therebetween, said flow passage including an inlet in communication with said supply of cooling fluid and an outlet in communication with said flow path, said flow passage supplying a first portion of cooling fluid from said supply of cooling fluid to said flow path; and

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a plurality of swirl members in said flow passage extending between said forward and aft wall structures, said swirl members each including a leading edge and a trailing edge spaced from said leading edge in a radial direction, wherein said trailing edge is offset from said leading edge in the circumferential direction;

wherein a flow direction of the first portion of cooling fluid passing through said flow passage is altered by said swirl members such that the first portion of cooling fluid has a velocity component in a direction tangential to the circumferential direction when the first portion of cooling fluid enters said flow passage;

at least one bypass passage defined through said shaft cover structure, said at least one bypass passage receiving a second portion of cooling fluid from said supply of cooling fluid, said at least one bypass passage including an exit opening at an end of said shaft cover structure supplying the second portion of cooling fluid to a turbine rim cavity associated with a first row vane assembly to prevent hot gas ingestion into the turbine rim cavity from a hot gas flow path associated with a turbine section of the engine; and

a metering structure associated with an outlet of said at least one bypass passage, said metering structure comprising a corresponding flow passageway formed therein in communication with the outlet of each respective bypass passage for permitting the second portion of cooling fluid in said at least one bypass passage to pass into the turbine rim cavity, wherein at least one of said flow passageways is formed in said metering structure at an angle such that the second portion of cooling fluid flowing out of said at least one flow passageway has a velocity component in the direction tangential to the circumferential direction;

wherein:

said shaft cover structure comprises a plurality of struts spaced apart from each other in the circumferential direction;

inlet openings to said pre-swirl structure are defined between adjacent struts; and

at least an upstream portion of said at least one bypass passage extends through a corresponding one of said struts.

2. The gas turbine engine according to claim 1, further comprising an air separator structure between said shaft and said shaft cover structure and having a portion extending axially from said pre-swirl structure to a location adjacent to a blade disc structure coupled to said shaft, said air separator structure and said shaft cooperating to define said flow path therebetween.

3. The gas turbine engine according to claim 2, wherein said air separator structure comprises a plurality of openings therein adjacent to said outlet of said pre-swirl structure, said openings permitting the first portion of cooling fluid to pass from said pre-swirl structure into said flow path.

4. The gas turbine engine according to claim 2, further comprising sealing structure downstream from said pre-swirl structure and located between said air separator structure and said shaft cover structure, said sealing structure limiting leakage between said outlet of said flow passage and the turbine rim cavity.

5. The gas turbine engine according to claim 4, wherein said pre-swirl structure and said shaft cover structure do not rotate with said shaft and said air separator structure rotates with said shaft during operation of the gas turbine engine.

6. The gas turbine engine according to claim 1, further comprising blade disc structure coupled to said shaft at a

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location axially downstream from said pre-swirl structure, said blade disc structure having at least one bore formed therein, said at least one bore receiving cooling fluid from said flow path and delivering the cooling fluid from said flow path to structure to be cooled within a turbine section of the engine. 5

7. The gas turbine engine according to claim 1, wherein said swirl members are configured such that the cooling fluid exiting said flow passage flows at an angle of from about 75° to about 85° relative to a radial axis of the gas turbine engine transverse to the central axis. 10

8. The gas turbine engine according to claim 1, wherein said swirl members are arranged such that a spacing between a first sidewall at said trailing edge of each said swirl member and a second sidewall of an adjacent swirl member causes a Venturi effect as the cooling fluid flows through said flow passage, the Venturi effect resulting in a pressure drop and a velocity increase of the cooling fluid flowing through said flow passage. 15

9. The gas turbine engine according to claim 1, wherein: said shaft cover structure comprises inner and outer shaft covers, said outer shaft cover structurally supported by an engine casing and providing structural support for said inner shaft cover; said supply of cooling fluid comprises a chamber located between said inner and outer shaft covers; and said pre-swirl structure is coupled to said inner shaft cover. 20

10. The gas turbine engine according to claim 1, wherein each said flow passageway is formed in said metering structure at an angle such that the second portion of cooling fluid flowing out of each said flow passageway has a velocity component in the direction tangential to the circumferential direction. 25

11. A gas turbine engine having a central axis defining an axial direction comprising:

- a supply of cooling fluid;
- a rotatable shaft extending in the axial direction of the engine;

- shaft cover structure disposed about said shaft such that a flow path extends in the axial direction between said shaft and said shaft cover structure;

- pre-swirl structure coupled to said shaft cover structure and located radially between said supply of cooling fluid and said flow path, said pre-swirl structure extending in a circumferential direction about said shaft, said pre-swirl structure comprising:

- a flow passage including an inlet in communication with said supply of cooling fluid and an outlet in communication with said flow path, said flow passage supplying a first portion of cooling fluid from said supply of cooling fluid to said flow path; and

- a plurality of swirl members in said flow passage, said swirl members each including a leading edge and a trailing edge spaced from said leading edge in a radial direction, wherein said trailing edge is offset from said leading edge in the circumferential direction;

wherein a flow direction of the first portion of cooling fluid passing through said flow passage is altered by said swirl members such that the first portion of cooling fluid has a velocity component in a direction tangential to the circumferential direction when the first portion of cooling fluid enters said flow passage; 30

- a plurality of bypass passages associated with said shaft cover structure, said bypass passages receiving a second portion of cooling fluid from said supply of cooling fluid and supplying the second portion of cooling fluid to a turbine rim cavity associated with a first row vane assembly to prevent hot gas ingestion into the turbine 35

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- rim cavity from a hot gas flow path associated with a turbine section of the engine; and

- a metering structure associated with an outlet of each said bypass passage, said metering structure comprising a plurality of flow passageways formed therein at outlets of said bypass passages for permitting the second portion of cooling fluid in said bypass passages to pass into the turbine rim cavity, wherein at least one of said flow passageways is formed in said metering structure at an angle such that the second portion of cooling fluid flowing out of said flow passageways has a velocity component in the direction tangential to the circumferential direction;

wherein said shaft cover structure comprises a plurality of struts spaced apart from each other in the circumferential direction, said struts defining inlet openings to said pre-swirl structure therebetween, wherein at least an upstream portion of each said bypass passage extends through a corresponding one of said struts. 40

12. The gas turbine engine according to claim 11, wherein said pre-swirl structure further comprises:

- forward wall structure; and

- aft wall structure spaced in the axial direction from said forward wall structure, said forward and aft wall structures defining said flow passage therebetween and said swirl members extending from said forward wall structure to said aft wall structure. 45

13. The gas turbine engine according to claim 11, wherein: said shaft cover structure comprises inner and outer shaft covers, said outer shaft cover structurally supported by an engine casing and providing structural support for said inner shaft cover;

- said supply of cooling fluid comprises a chamber located between said inner and outer shaft covers;

- said pre-swirl structure is coupled to said inner shaft cover; and

- said bypass passages are associated with said inner shaft cover. 50

14. The gas turbine engine according to claim 11, further comprising:

- an air separator structure between said shaft and said shaft cover structure, said air separator structure and said shaft cooperating to define said flow path therebetween;

- first sealing structure located radially between a first axially extending portion of said air separator structure and said shaft cover structure and located axially between said bypass passages and said pre-swirl structure, said first sealing structure limiting leakage between said bypass passages and said outlet of said flow passage; and

- second sealing structure located radially between a second axially extending portion of said air separator structure and said shaft cover structure and located axially between said pre-swirl structure and said turbine rim cavity, said second sealing structure limiting leakage between said outlet of said flow passage and said turbine rim cavity. 55

15. The gas turbine engine according to claim 11, further comprising blade disc structure coupled to said shaft at a location axially downstream from said pre-swirl structure, said blade disc structure having at least one bore formed therein, said at least one bore receiving the first portion of cooling fluid from said flow path and delivering the first portion of cooling fluid to structure to be cooled within the turbine section of the engine. 60

16. The gas turbine engine according to claim 11, wherein said shaft cover structure comprises at least one cooling fluid port formed therein for permitting cooling fluid to flow into a 65

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chamber in communication with a compressor section of the engine for cooling structure to be cooled in the compressor section.

17. A gas turbine engine having a central axis defining an axial direction comprising: 5
 a supply of cooling fluid;
 a rotatable shaft extending in the axial direction of the engine;
 shaft cover structure disposed about said shaft such that a flow path extends in the axial direction between said shaft and said shaft cover structure; 10
 pre-swirl structure coupled to said shaft cover structure and located radially between said supply of cooling fluid and said flow path, said pre-swirl structure:
 extending in a circumferential direction about said shaft; 15
 defining a flow passage including an inlet in communication with said supply of cooling fluid and an outlet in communication with said flow path, said flow passage supplying a first portion of cooling fluid from said supply of cooling fluid to said flow path; and 20
 comprising a plurality of swirl members in said flow passage, said swirl members each including a leading edge and a trailing edge spaced from said leading edge in a radial direction, wherein said trailing edge is offset from said leading edge in the circumferential direction, wherein a flow direction of the first portion of cooling fluid passing through said flow passage is altered by said swirl members such that the first portion of cooling fluid has a velocity component in a direction tangential to the circumferential direction 25
 when the first portion of cooling fluid enters said flow passage;
 a plurality of circumferentially spaced apart and axially extending bypass passages receiving a second portion of cooling fluid from said supply of cooling fluid, said 30
 bypass passages each including an exit opening proximate to an end of said shaft cover structure and supplying the second portion of cooling fluid to a turbine rim cavity associated with a first row vane assembly, wherein inlet openings to said pre-swirl structure are defined between structure that defines at least upstream portions of said bypass passages; and 35

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a metering structure associated with outlets of said bypass passages, said metering structure comprising corresponding flow passageways formed therein in communication with said outlet of each respective bypass passage for permitting the second portion of cooling fluid in said bypass passages to pass into the turbine rim cavity, wherein at least one of said flow passageways is formed in said metering structure at an angle such that the second portion of cooling fluid flowing out of said at least one flow passageway has a velocity component in the direction tangential to the circumferential direction.
 18. The gas turbine engine according to claim 17, wherein said shaft cover structure comprises bores that define each of said bypass passages.
 19. The gas turbine engine according to claim 17, wherein: said shaft cover structure comprises inner and outer shaft covers, said outer shaft cover providing structural support for said inner shaft cover;
 said supply of cooling fluid comprises a chamber located between said inner and outer shaft covers;
 said pre-swirl structure is coupled to said inner shaft cover; and
 said bypass passages are formed in said inner shaft cover.
 20. The gas turbine engine according to claim 17, wherein each said flow passageway is formed in said metering structure at an angle such that the second portion of cooling fluid flowing out of each said flow passageway has a velocity component in the direction tangential to the circumferential direction.

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